

**Final Report**

**Project No. A-3363**

## **TAC LOADER DOOR REDESIGN**

**Prepared by:**

**Anthony D. Jape  
Project Director**

**Submitted to:**

**Warner Robins Air Logistics Center  
Robins Air Force Base, Georgia**

**May 1984**

## **GEORGIA INSTITUTE OF TECHNOLOGY**

**A Unit of the University System of Georgia  
Engineering Experiment Station  
Atlanta, Georgia 30332**



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## I. Introduction

The Georgia Tech Engineering Experiment Station, under contract to the Warner Robins Air Logistics Center, conducted an investigation into the structural failure of cab doors on the model A/S 32H-19 Aircraft Cargo Loading/Unloading Truck. The initially stated scope of activity for this study included the following tasks:

- Inspection of doors installed on loaders and discussion with Air Force personnel as to difficulties encountered in service.
- Detailed examination of a failed door unit.
- Redesign of the door to solve the problem of structural failures.
- Construction and testing of a prototype door.
- Preparation of documentation on the redesigned door.

Several difficulties were encountered in obtaining information and specimen doors in a timely manner. In addition, the study revealed that there are numerous failure points on the

doors and that design flaws in the door were only a part of overall structural design inadequacies in the cab.

For these reasons, a complete redesign of the entire cab structure was considered warranted. As an interim measure, a modified scope of work was proposed, involving development of a field modification kit. The proposed kit would provide adequate structural improvements to both the cab and the door to alleviate the unsatisfactory performance. The statement of work for this proposal is presented in Appendix A.

The sponsor elected not to pursue this solution to the problem and instead to end the project and pursue other alternatives. This report summarizes the activities and findings of the work completed under the contract.

## II. Background

The A/S 32H-19 truck is a special purpose vehicle designed for flexibility in loading and unloading cargo at various heights to and from aircraft at terminal docks. The truck deck will adjust in both height and tilt in order to accommodate various loading requirements. In addition, the truck is capable of on- and off-loading cargo from its deck to the ground with winches. In its basic configuration, the truck has a load capacity of 25,000 pounds of palletized cargo. The truck is illustrated in Figure 1.

The one-man cab is located on the left forward side of the truck and is attached to the deck so as to raise and lower with the load. The cab may be swung inward to a stowed position in which it does not extend beyond the edge of the deck. This position is used for air shipment and road travel.

Two folding steps and two handgrips are located on the left rear side of the cab wall, and a grab handle is located on the rear cab wall. These are intended to aid entry to both the cab and the cargo deck catwalk. A portable step is provided for use in entering the cab. It is transported in the cab and secured behind the seat.

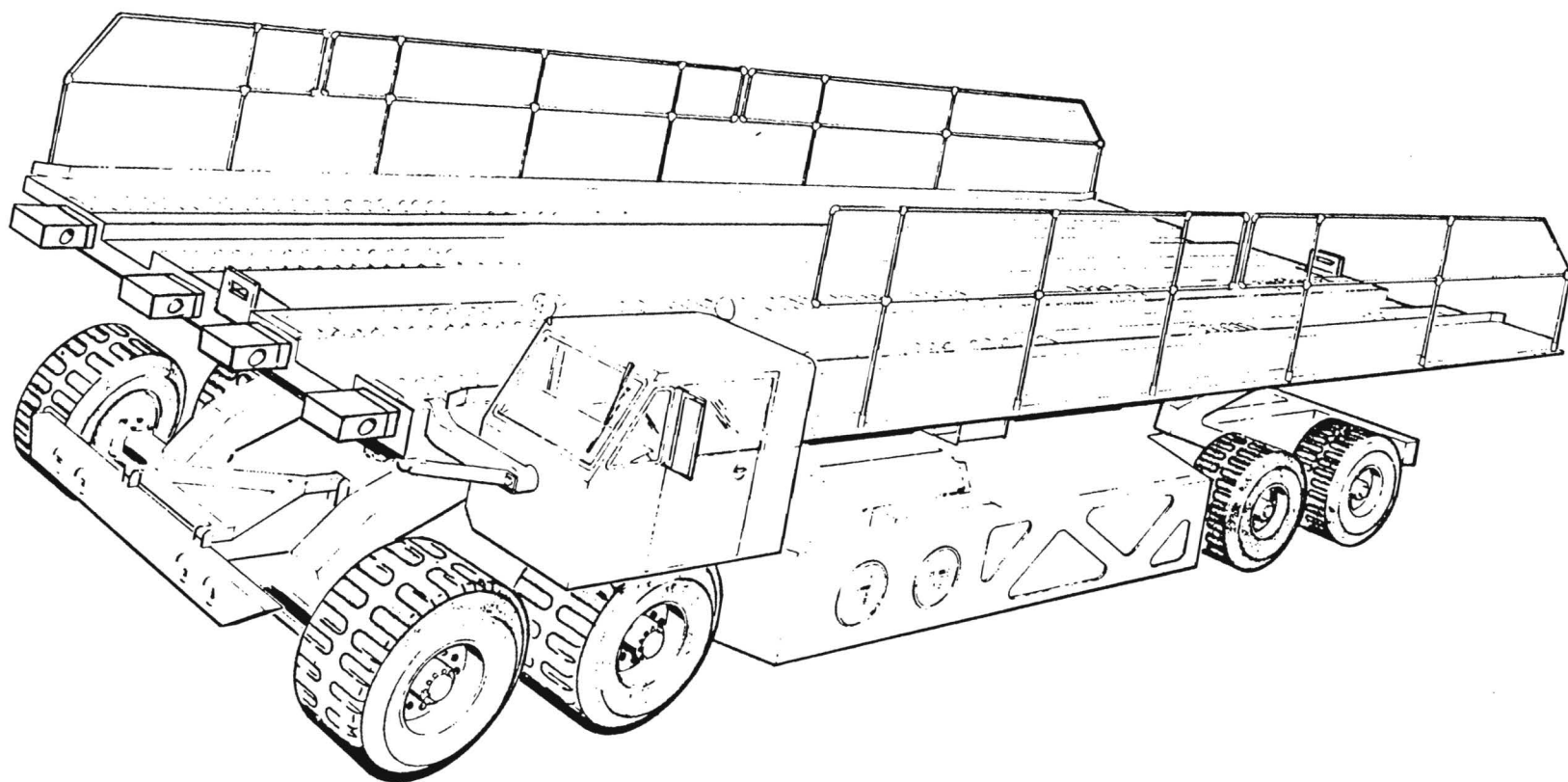


Figure 1. A/S 32H-19 CARGO LOADER



The cab door, illustrated in Figure 2, consists primarily of two sheet metal panels, a window rim attached with screws, the window glass, window operating mechanism, and the handle/latch mechanism.

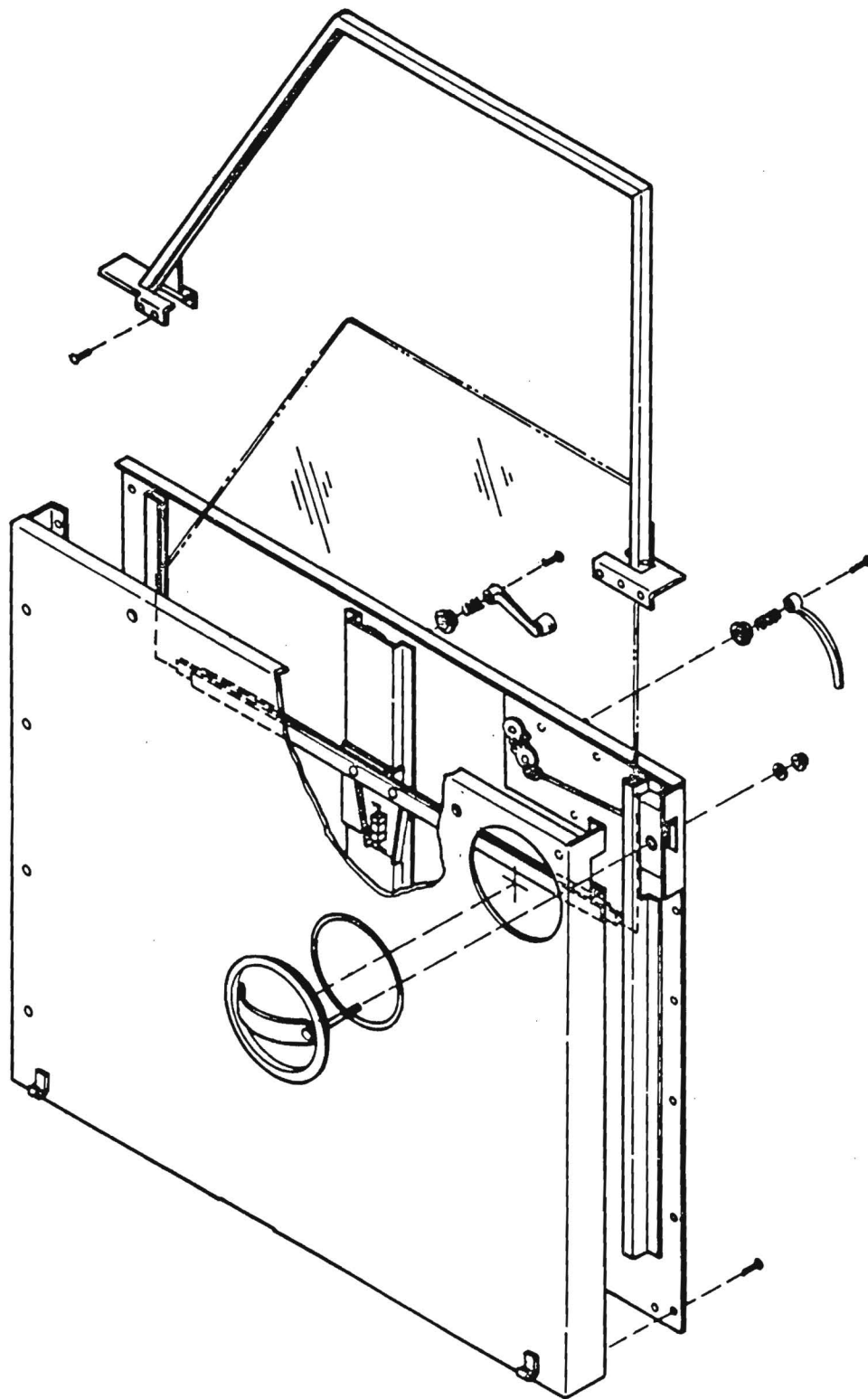


Figure 2. LOADER CAB DOOR ASSEMBLY

### III. Description of the Problem

The cab door has been a continuing source of difficulty, with numerous service failures having been encountered. Discussions with Air Force personnel indicated that the doors experience substantial damage during their first year of use with continuing deterioration afterward. The failures are due to design inadequacies, so that there is no satisfactory field repair technique, and even complete replacement of the door offers only a temporary solution. As a result, doors regularly remain in use after they reach an unserviceable condition.

Georgia Tech personnel performed a visual examination of the six TAC loaders based at Pope Air Force Base, North Carolina. Several major problem areas were identified and found to be common to all of these loaders:

- Severe cracking of the window frame, glass run and supports, resulting in loss or breakage of the glass.
- Loss of fasteners intended to retain major components of the door, resulting in extreme loss of rigidity.
- Failure of the hinge and hinge fasteners to maintain

alignment of the door.

Most of the cracks occur in highly stressed areas, including small radius bends and corners. This finding suggested the need for failure mode analyses to determine whether the components experienced excessive stresses during fabrication or service or perhaps failed due to cyclical stress fatigue. Such testing was proposed as part of an expanded scope of work.

The lack of a continuous door frame severely limits the structural rigidity which can be attained. The design assumes that rigidity is derived from the components being securely fastened to form a shell. The two door panels are held together with screws, many of which were found to be missing, possibly due to vibration. Many of the threaded inserts which anchor these screws fail or pull out of their mounting points.

Misalignment of the door causes substantial wear and impact damage to the edges of the door and the surrounding cab panels. The misalignment is caused both by radial and axial wear in the hinge and by looseness in the hinge-to-door and hinge-to-cab mounting points. The fasteners at these mounting points are being subjected to local stresses which exceed their capacity.

In addition to these major problems, several contributing factors were identified as having an impact on the failure of the doors:

- Numerous cracks not only in the door panels but also in the surrounding cab panels. The loss of rigidity which results promotes further deterioration of the structure.
- Inadequate assist handles and steps for personnel to enter the cab. The detachable step is not convenient, while the door itself is an attractive assist handle. The loads applied to the door and hinges exceed the capacity of the design.
- A general lack of rigidity in the cab panels that mount the door and the latch striker plate. This is the result of failed cab components, loose or sheared rivets, and insufficient bracing of the panels.

These problems are important because they contribute to the failure of the door. Even if the door design is improved, the weaknesses in the design of the cab will lead to excessive door failures.

#### IV. Further Investigations

The initial scope of the study called for a detailed examination of a failed door unit. Considerable difficulty and delay was encountered in obtaining the specimen. As a substitute, a new door was obtained for examination five months after the start of the project. This door was disassembled and subjected to a preliminary examination. The fact that it had not been exposed to service and did not exhibit indications of typical failure modes limited the usefulness of the unit to the study.

Five months later, a used door was obtained and subjected to preliminary examinations. Since cracking had been observed near small radius bends on many doors in service, the match between specified and as-built radii was a primary concern. Table 1 presents the specified bend radii for several locations as well as the radii measurements for the used door.

Three of the four radii on the window frame bracket and gusset were approximately 40% less than the design specification. Bends on the door panels were approximately 20% sharper than specified. Other bends were measured at very near the specified radii.

Table 1. Specified and Measured Bend Radii

Position of Radius	Specified (inches)	Measured (inches)	*
Window frame bracket			
rear	0.13	5/64	(.078)
front	0.13	1/8	(.125)
Window frame gusset			
rear	0.13	5/64	(.078)
front	0.13	5/64	(.078)
Window support bracket			
"L" portion	0.06	3/64	(.047)
"Z" portion	0.06	1/16	(.063)
Inside door panel	0.08	1/16	(.063)
Outside door panel	0.08	1/16	(.063)
Window stop	0.12	1/8	(.125)

\* Radii were measured with a radius gage to 1/64 inch precision. Decimal equivalents are presented only for convenience in comparison.

Plans were developed to conduct detailed analyses of the failure mode of the door, to aid in developing an improved design. The Georgia Tech Fracture and Fatigue Research Laboratory prepared a test plan to be performed on specimens cut from the door. Tests to be conducted included:

- Tensile tests to determine mechanical properties.
- Optical metallography.
- Bend tests to determine the appropriateness of the material used.
- Scanning electron microscope examination to determine failure mechanism (fatigue vs. tensile overload).

Since these tests exceeded the limits of the original study and would require additional funding, they were included in the proposal submitted to the sponsor for an expanded study. Since the additional work has not been contracted, the failure analyses have not been performed.



## V. Recommendations

A proposal was submitted to the sponsor for development of a field installation kit which would alleviate difficulties with the cab and door structural performance. A preferred alternative is the complete redesign of the cab assembly.

The expanded scope of work also included investigations which were designed to develop a data base adequate for proper redesign of the door and/or cab. Finalizing these data is recommended if a redesign is eventually undertaken in order to avoid recurrence of the same problems.

In considering opportunities for design improvement, several potential barriers were identified, and clarification was requested on design constraints. Future designers should be advised of the responses to these requests.

The first topic involved material selection, acceptable alloys, and heat treatment processes. Use of light alloys is encouraged by the need to air lift the vehicle, but it also complicates the structural design process. The response which was received indicated that there were no restrictions on alloy and heat treatment selection except that the material must be

easily available.

The second topic involved permissible weight increases which might be required to obtain adequate structural integrity. The response indicated that a maximum weight increase of 15 pounds for the door was acceptable. A weight increase associated with a redesign of the entire cab was not addressed.

Finally, the lack of an integral frame for the window and door restricts the rigidity which can be achieved. It appears that the frame was omitted from the design in order to allow the vehicle to be converted to a reduced-overall-height configuration by removal of the cab roof. The response received on this inquiry stated that an integral door/window frame was acceptable and that it is not necessary for the window frame to be detachable, provided there is a means to replace the window glass.

The response to this third inquiry, by eliminating the need for the reduced-height mode, suggests that a unitized cab body/roof may be an acceptable design. Such a configuration could contribute substantially to the rigidity and structural durability of the cab and door.

In fact, it appears that such a design was developed at one time. A prototype of such a cab was observed at Pope Air Force Base, where it had been considered for local modification and installation. Georgia Tech does not have access to the entire

development history of the vehicle design, so the deficiencies and objections to the rigid cab design cannot be evaluated. However, the prototype which was observed appeared to offer numerous structural advantages over the current design and should be preferred if there is no requirement for operating the vehicle at a reduced height.

Development of a field installation kit is a viable alternative as an intermediate solution to the design weaknesses in the cab. Although such a kit has not been developed under this project and the modifications necessary in the door design have not been completely analyzed, several areas have been identified to which specific attention must be paid. These observations are presented as an aid in the event that such an intermediate solution is eventually undertaken:

1. Fasteners must be improved. The hinge is attached to the door and the cab with pop rivets -- a fastener type which is not suitable for supporting significant shear loads. Pop rivets are also used to attach many of the minor components to the door panels. Screwed fasteners which hold the door panels together are anchored with pop-in threaded inserts. These inserts are not secure. They rotate in place, preventing adequate tightening of the screws, while they will pull out completely if significant loads are applied. Two recommended methods are the use of

a backing bar to serve as the anchor for threaded fasteners and the use of conventional, driven rivets to form permanent attachments.

2. The quality of the hinge itself must be improved. Several hinge types are in use, most of which employ light weight alloys which are not heat treated. The added weight of a steel hinge may well be rewarded with improved performance.
3. The window guides and lift mechanism are not adequate to maintain proper orientation of the glass. As a minimum, the lift mechanism should be replaced with one which provides two separated lift points rather than the current single point.
4. The outside door handle and handle cup are not securely attached. Adequate provisions for holding the cup in place will improve performance.
5. The bend radii on the door panels should be increased to match the acceptable applications for the alloy used. These increases should appear not only in the drawings, but more importantly in the actual fabrication.
6. The window frame should be an integral part of the door. This may not be possible in a limited redesign, in which case a much more secure means of attaching the removable

frame should be implemented.

7. Improved means should be provided for access to the cab. The removable steps are inconvenient and encourage the use of the open door as a handle for climbing in. This maneuver places excessive loads on the hinge and mounting points. A permanently-mounted, retractable ladder that can be easily positioned from both the ground and the cab should be considered as a candidate solution to this problem.

Appendix A

SCOPE OF PROPOSED ADDITIONAL WORK

## Appendix A

### SCOPE OF PROPOSED ADDITIONAL WORK

The original statement of work consisted of the following five steps:

1. Inspection -- Final inspection of the problem doors and discussions with Air Force personnel.
2. Example Procurement -- If possible, an example of the problem door will be obtained and brought to Georgia Tech for further inspection.
3. Redesign -- Components of the door will be redesigned to solve the problems with hinges, window rigidity and window operation.
4. Prototype Construction -- Fabrication, test and evaluation using example door as base.
5. Drawings, Documentation -- A complete set of drawings will be prepared to document the redesign of the door to solve the problems and a brief final report will be prepared to explain the findings.

To perform Step 1, Georgia Tech personnel traveled to Pope AFB, North Carolina, to meet with Sergeant O. C. Salinas and perform a visual examination of the TAC loader. Sergeant Salinas showed us the 6 TAC loaders based at Pope, and a thorough visual examination was made of the door and surrounding cab panels on each of these.

The following major problem areas were identified and found to be common to all of the loaders examined:

1. Severe cracking of the window frame, glass run and supports, resulting in loss or breakage of window glass. Most of the cracks are occurring in highly stressed areas, including small radius bends and corners.
2. Loss of fasteners intended to retain major components of the door, resulting in extreme loss of rigidity. The loss of these fasteners appears to be partly due to vibration and partly due to failure and pullout of threaded inserts.
3. Failure of hinge and hinge fasteners to maintain alignment of the door. The resulting misalignment of the door causes

excessive wear and impact damage to the edges of the door and surrounding cab panels. The misalignment of the door is caused by two wear modes working in parallel. One mode is excessive looseness in the hinge caused by wear occurring in both the radial and axial directions. The major wear component was observed to be in the axial direction. Three different hinge designs were in use and each exhibited slightly different wear characteristics. The other wear mode is radial and axial looseness caused by the hinge fasteners at the hinge to door and hinge to cab mounting points. The fasteners are being subjected to local stresses which exceed their capacity.

In addition to the preceding major problems, the following contributing factors were identified as having an impact on the failure of the doors:

1. Numerous fatigue cracks in the door and surrounding cab panels. This results in a general weakening and loss of rigidity in the whole structure, promoting rapid further deterioration of the structure. Many of these cracks are occurring at small radius bends and in highly stressed support bracing.
2. A lack of carefully placed assist handles and steps for personnel to enter cab results in excessive force being applied to the door and hinge structure on certain occasions. The detachable step provided with the vehicle is not sufficient to provide easy access to the cab. An improved access arrangement that would allow personnel to enter the cab without applying significant force to the door would greatly increase the life of the door and hinge assembly.
3. A general lack of rigidity in the cab panels that mount the door and the latch striker plate. This is a result of fractured components, loose or sheared rivets, and a lack of sufficient bracing of the cab panels surrounding the door opening.

These problems are important in that they occur independently of the problems occurring within the door, and they can independently cause door failure. The entire cab structure is suffering from the same basic problems as the door, and the door problems cannot be completely solved without addressing some of the contributing factors in the surrounding cab panels.

In order to provide an effective solution to the problems enumerated above, we propose to expand the statement of work to include the cab to the extent necessary to address its most serious problems. The expanded work statement would consist of



the following five steps:

1. Inspection -- Additional inspection of the cab and discussions with Air Force personnel will be required.
2. Example Procurement -- Samples of a damaged and an undamaged door have already been procured. A sample of a damaged cab assembly would greatly improve the speed and allow greater detail in the redesign work.
3. Redesign -- Components of the door will be redesigned to solve the problems with hinges, window operation and general rigidity. For the cab, we are planning to design a retrofit package consisting of redesigned components and additional structural bracing that can be field installed. We are also planning to investigate some alternative methods for improving operator access to the cab. It is believed that this will result in the design of a field installable retrofit package that will significantly improve operator access to the cab.
4. Prototype Construction -- Fabrication, test and evaluation using example door and cab as base.
5. Drawings, Documentation -- A complete set of drawings will be prepared to document the redesign of the door and cab structure. A brief final report will be prepared to explain the findings.